An Agent-based Approach to Group Decision Simulation using Argumentation

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Abstract. Group decision making simulation allows for the creation of virtual group decision scenarios. The use of a group decision simulator enhances user competences in this area, to test different argumentation strategies and to validate "what if" useful real world scenarios. In this paper, it is proposed a multi-agent model to simulate group decision making tasks. Agents are designed with emotional properties, reason with incomplete information and use persuasive argumentation to convince the other group elements about the best alternative choice.

1 Introduction

The group decision and negotiation terms are used many times in the same context, essentially because group decision making involves discussion or negotiation to achieve a common decision. But group decision and negotiation processes are quite different. Some of the major differences are:

- In group decision making, the alternatives are already settled (in the choice moment); in negotiation the alternatives are sequentially presented and modified for the involved parties;
- The information sharing process is usually more important in group decision;
- The voting mechanisms can be a possibility in group decision; in negotiation they do not make sense;
- In a negotiation process, it is more frequent that one of the parties leaves negotiation;
- The main objectives in group decision are usually common while in negotiation they are usually antagonist. However, in some contexts, the group members can have very dissident objectives, what will imply the use of negotiation in order to achieve a good solution.

Group decision making and negotiation processes represent very complex human activities. A better understanding of those processes implies the relation of several disciplines as, for instance, psychology, sociology, political science, etc. Since a few years ago, specialists in decision making area started to consider emotion as a significant factor of influence in the process [1][2][3]. In psychological literature, several examples could be found on how emotions and moods affect the individual decision making process. For instance, individuals are more predisposed to recall memories that are congruent with their present emotional state. There are also experiments that relate the influence of emotional state in information seeking strategies and decision procedures.

Along the last 20 years, several Group Decision Support Systems were developed, some dedicated to be used exclusively in decision rooms and other ones with features to support ubiquitous group decision meetings [4][5][6].

Recent growing interest in artificial agents and their potential application in simulation areas such as: individual decision making ("what-if" scenarios), e-commerce (to simulate the buyers and sellers behaviour), crisis situations (e.g. fire combat simulation), traffic simulation, military training, entertainment (e.g. movies) have given increased importance to automated negotiation.

In the multi-agent literature, various interaction and decision mechanisms for automated negotiation have been proposed and studied. Traditional mechanisms include game-theoretic analysis [7][8] and heuristic-based approaches [9][10]. Other approach to automated negotiation are the argumentation-based approaches [11][12][13][14].

In the context of negotiation, argumentation is viewed as a mechanism to make possible the information exchange. An argument is viewed as a piece of information that may allow for an agent to [13]:

- Justify its negotiation decision or option; and
- Influence others agents about the quality of its proposals.

A group decision making process involves multiple actors, each one with different expertises, preferences, perspectives of the problem and different emotional states. Many times, different types of conflicts and disagreements arise, and it is necessary to overcome them. Argumentation is used in every day dialogues by parents, students, doctors to justify choice or to convince the interlocutor about their point of views. Also, in group decision domain, argumentation can be an excellent way to justify possible choices and to convince other elements of the group about the best or worst alternative.

It is proposed a multi-agent model to simulate group decision making processes, where agents are designed with emotional properties and reason with incomplete information. Agents use persuasive argumentation for convincement and the best choice. The application area of this model is the multi-criteria decision problems. The multi-criteria decision process aims to evaluate a set of alternatives relatively to a number of criteria which are conflicting in nature.

This paper is structured as follows. Section 2 presents the multi-agent model to simulate group decision processes. Section 3 describes the group decision protocol used in simulation. In section 4 it is presented the participant agents architecture and detailed its main components and interactions. Section 5 presents some experiments made with a first version of the implemented prototype, and finally section 6 presents some conclusions.

2 MULTI-AGENT MODEL

There are different types of agents in our model: Facilitator agent, Voting agent, Information agent and Participant agents. Figure 1 illustrates the proposed multi-agent model.

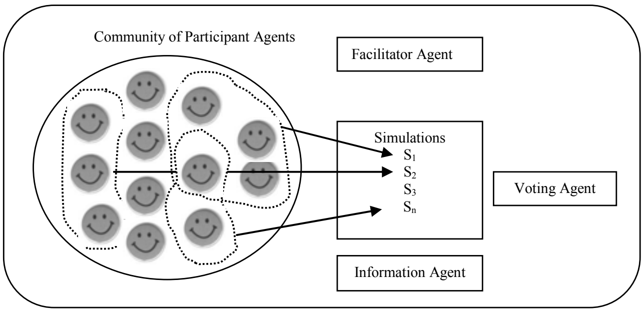

Figure 1 - Multi-agent model to simulate group decision

The Facilitator Agent will help the simulation responsible in its organization (e.g. decision problem and decision rules configuration). The Facilitator Agent administrates the group formation process (selection of the participant agents). This agent will also manage the inclusion of new participant agents in the community. During the simulation, the facilitator agent will coordinate and, at end, will summarize the simulation results.

By experience, it is known that almost all the group decision making meetings have one or more voting rounds. The Voting Agent will execute the tasks related with the voting simulation process, according to the decision rules settled by the Facilitator Agent.

The Information Agent holds information about the different proposals (alternatives) that will be evaluated by the group of agents during the group decision making simulation.

The Participant Agents will simulate according to the role of the persons in the group decision making process. The set of Participant Agents form a community where the agents are created with social and emotional properties that will personalize its behaviour. Each agent will have a model of itself, a model of the other agents and a model of the community where it holds. By the simulation analyse, the agent will construct the other agent profile, particularly relating: benevolence, credibility, preferred arguments and emotional states. These models may contain imprecise, ambiguous and incomplete information and, for that reason, the agents incorporate information quality evaluation in their individual reason process.

The structure of the Participant Agent structure will be detailed in section 4.

3 GROUP DECISION PROTOCOL

3.1 Decision Problem Configuration

The alternatives are identified by the Participant Agents. Let $A=\{A_1,A_2,\ldots,A_n\}$ be an enumerated set of n alternatives, where n>=2. The criteria are also known. Let $C=\{C_1,C_2,\ldots,C_m\}$ be an enumerated set where m>=2. The decision matrix will be composed by n alternatives and m criteria. Let $D=[D_{ij}]_{nxm}$ where D_{ij} represents the value of alternative Ai respectively to criterion Cj, and i=1,…n, j=1,…m.

The participants of a specific simulation belong to the set $AgP=\{AgP_1,\ldots AgP_k\}$, where k is the number of participants and k>=2. Each AgP_i is related with a set of weights for the criteria. Let $W_{AgPi}=\{ W_{C1},\ldots W_{Cm}\}$ the set of weights for AgPi, where $\sum_{j=1}^{m} W_{C_j} = 1,\ W_{C_j} \geq 0$.

3.2 Decision Protocol

It is possible to find several classifications of decision models for problem solving. One of the most used is Simon’s classification that identifies the following phases: intelligence, design, choice and implementation [3]. In our model, it is focused the choice phase. We may consider that there is a pre-decision phase where the decision problem is configured as well as the simulation parameters (e.g. approving rule, duration).

In figure 2 it is possible to see the proposed group decision protocol.

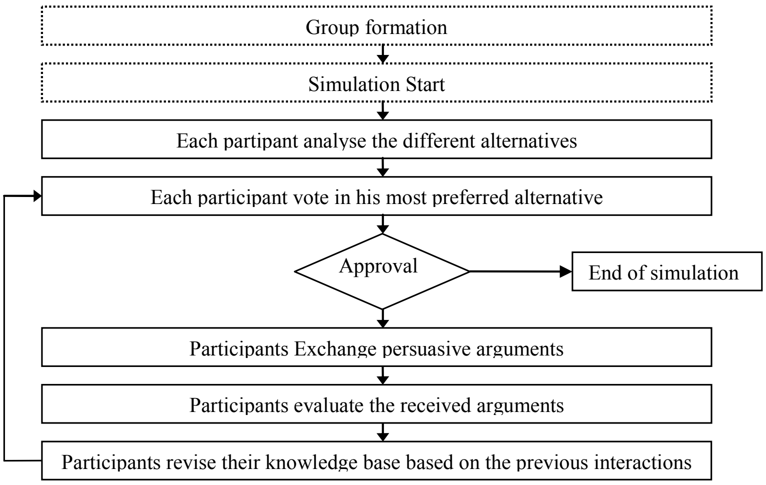

Figure 2 - Group decision protocol

Before starting simulation, a simulation group must be formed. This task is performed by the Facilitator Agent and based on the knowledge about each participant [25].

After starting the simulation, each Participant Agent establishes its individual preferences, classifies alternatives (section 4.2) and votes according to the preferred alternatives. If following the decision rules, there is already an approval, the simulation ends, otherwise, the argumentation process begins (section 4.3 and 4.4). Before a new voting round, the Participant Agents revise their knowledge bases using previous interactions. The simulation may finish with an approval selecting a specific alternative or without approval (timeout).

4 PARTICIPANT AGENTS ARCHITECTURE

In figure 3, it is represented the architecture of Participant Agents. This architecture contains three main layers: the knowledge layer, the reasoning layer and the communication layer.

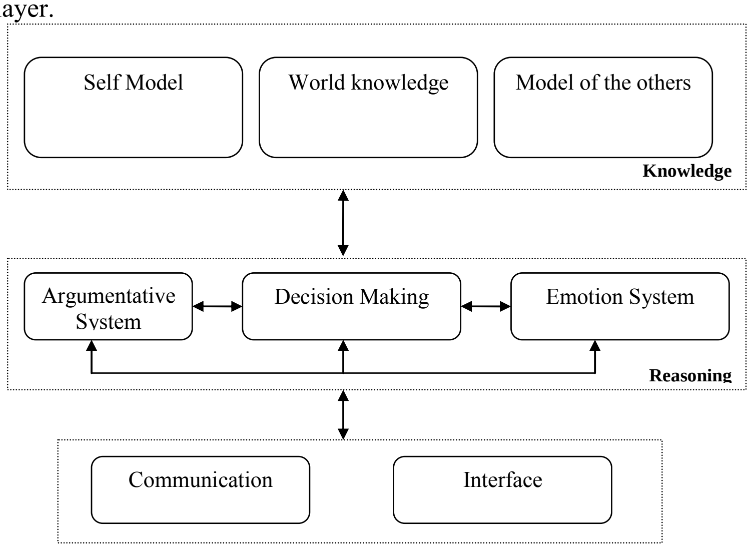

Figure 3 - Participant Agents structure

4.1 Knowledge Representation

The Participant Agents Knowledge Bases (KB) are made of logic clauses of the form $r_k{:}P_{i+j+1} \leftarrow P_1 \wedge P_2 \wedge \ldots \wedge P_{i-1} \wedge \text{not } P_i \wedge \ldots \wedge P_{i+j}$, where i, j, k $\in N_0$, $P_1, \ldots, P_{i+j}$ are literals; i.e., formulas of the form p or $\neg$ p, where p is an atom, $\neg$ stands for explicit negation and where r_k, not, P_{i+j+1}, and $P_1 \wedge P_2 \wedge \ldots \wedge P_{i-1} \wedge \text{not } P_i \wedge \ldots \wedge P_{i+j}$ stand, respectively, for the clause's identifier, the **negation-by-failure** operator, the rule's consequent, and the rule's antecedent. If i=j=0 the clause is called a **fact** and is represented as r_k:P_1.

This work is supported by the developments in [16] where the representation of incomplete information and the reasoning based on partial assumptions is studied, using the representation of null values [17] to characterize abnormal or exceptional situations.

Definition 1 - Meta theorem-solver for incomplete information
A meta theorem-solver for incomplete information, represented by the signature demo:T,V→{true,false}, infers the valuation V of a theorem T in terms of false, true and unknown according to the following set of productions:

$$\begin{array}{l} demo(T,true) \leftarrow T. \\ demo(T,false) \leftarrow \neg T. \\ demo(T,unknown) \leftarrow not\ T, \\ \qquad\qquad\qquad\qquad\quad not\ \neg\ T. \end{array}$$

The Knowledge Base of a Participant Agent KB_{AgP} is:
$KB_{AgP} = AgP_iO\ U\ AgP_iOO\ U\ AgP_iP\ U\ AgP_iPO$, where AgP_iO are the goals of agent AgP_i, AgP_iOO are the set of goals that AgP_i believes the other agents hold, AgP_iP contains the model of its own profile and AgP_iPO contains what AgP_i believes about the other agents profile.
The AgP_iPO is defined according to a set of characteristics enumerated afterward: emotional state, gratitude debts, credibility [18][19], enemies, benevolent, time dependence and preferred arguments. An example is presented as it follows.

exception $_{\text{EmotionalState}}$ ('A',positive).
exception $_{\text{EmotionalState}}$ ('A',neutral).
exception $_{\text{EmotionalState}}$ ('A',negative).
¬ EmotionalState (A,B):-
  not EmotionalState (A,B),
  not exception $_{\text{EmotionalState}}$ (A,B).
exception $_{\text{EmotionalState}}$ (A,B):-
  EmotionalState (A, unknown).

In this example, the agent AgP does not know the agent B emotional state.
In the argument selection process, besides the information that agent detains, it is important to set the quality of that information. For evaluating the quality of the information, the following quality operators are defined: $Q_{EmotionalState}$, $Q_{Gratitude}$, $Q_{Credibility}$, $Q_{Enemies}$, $Q_{Benevolent}$, $Q_{TimeDependent}$, $Q_{PreferredArguments}$.

where the quality of the information about the property K is given by: $Q_K = 1/Card$, $Card$ is the cardinality of the exception set for K.
The quality of the information that agent AgP_i detains about agent AgP_j, is measured by the following formula:

$$Q^{AgP_i}(Profile_{AgP_j}) = \frac{\sum_{k=1}^{N} Q_k^{AgP_j} * W_k^{AgP_i}}{\sum_{k=1}^{N} W_k^{AgP_i}}$$

where N is the number of properties of the profile, Q_k^{AgPj} is the quality measure of K and $W_k^{AgP_i}$ (in interval [0,1]) represents the contribution of K (weight) in the agent profile construction. A property with weight 0 will not be considered in the profile construction process.

4.2 Decision Making

In the first phase the agents use the decision making component to establish individual preferences; they can use a simple additive function or a more sophisticated method like for instance AHP (Analytical Hierarchical Process). After that step, Participant Agents divide the set of alternatives in three classes according to the initial preferences: preferred, indifferent and inadmissible classes. To make this distribution, the first two phases of NAI (Negotiable Alternatives Identifier) algorithm [20] will be used. The NAI algorithm proposes a classification (e.g., preferred or indifferent) and this classification may change because in group decision scenarios some alternatives may be really inadmissible for a specific participant. This classification will allow for adding information to the AgP_iO knowledge base (KB that contains information about the agent goals).

4.3 Argumentative System

This component will generate persuasive arguments based on the information that exists in the Participant Agent knowledge base. We adopt the same ontology as in [14][21]. So, we have the following arguments: appeal to prevailing practice; a counter example; an appeal to past promise; an appeal to self-interest; a promise of future reward; and a threat.

In [14] it is used an existent pre-order for the selection of arguments to send, the strongest argument is a threat and the weakest argument is an appeal to prevailing practice. In [21] the selection is based on mixture of the alternatives utility and the trust in the interlocutor. In our model, the selection of arguments and the selection of the agent to persuade are based on the agent emotional state, in the information belonging to the interlocutor profile and in the quality of that information [22]. A Participant Agent classifies the alternatives (according to the utility) into three classes: most preferred, indifferent and unacceptable. Each agent has its own goal related strategy that defines if the agent will argue to defend the most preferred alternatives or if it will argue to avoid that one of the unacceptable alternatives is selected by the group. We adopt the scale proposed in [14] for the definition of strong and weak arguments.

An example of a threat may be:

AgP1 asks AgP2 to vote on alternative Ai with the argument that if it refuses it will vote on alternative Aj that it believes it is inadmissible for AgP2.

In the evaluation of arguments, agents consider the following factors: its own goal related strategy, the utility of the proposal, the strength of the argument and the credibility of the opponent.

4.4 Emotional System

The simulated emotions in our system are the ones identified in the reviewed version of the OCC (Ortony, Clore and Collins) model: joy, hope, relief, pride, gratitude, like, distress, fear, disappointment remorse, anger and dislike [23].

An emotion in our system is characterized by the following properties: if it is positive or negative, starting simulation time, agent identification or event that causes the emotion and emotion intensity.

The Facilitator Agent will support the setup of a set of rules to configure the emotion generation. The system is prepared to allow the configuration of all the set considered in the reviewed OCC model, but the administrator may opt just to configure a subset of it.

The emotional system is composed by three major blocks: appraisal, selection and decay [24].

5 PROTOTYPE

A prototype of the proposed multi-agent model is being under development. The Open Agent Architecture (OAA) [26] was chosen as the development platform. OAA is structured in order to minimize the effort involved in the creation of new agents written in different languages and operating on heterogeneous platforms; to encourage the reuse of existing agents; and to allow for dynamics and flexibility in the make-up of agent communities. In our prototype, we developed the Participant Agents in Prolog and other agents in Java (the communication is supported through Inter-agent Communication Language – ICL).

6 CONLUSIONS

This work proposes a multi-agent model to simulate group decision making processes, where agents are designed with emotional properties and reason with incomplete information. The discussion process between group members is made through the exchange of persuasive arguments.

In this model, each group decision member is represented by a separate agent, which facilitates the simulation of persons with different behaviour. The inclusion of an emotional module will help users to obtain a better representation of the reality.

Initially, each agent has its own preferences and votes according to them, but those preferences evolve the arguments exchange process.

Future work will privilege the refinement of this model, will go on implementation and will do experiments (e.g. combining emotional agents with purely rational agents in the same simulation group and observing the achieved results).

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